

**BIOLOGICAL INTEGRITY OF LAKE CREEK
(BENTON LAKE WATERSHED)
BASED ON THE STRUCTURE AND COMPOSITION OF
THE BENTHIC ALGAE COMMUNITY**

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Summary

In September 2004, periphyton samples were collected from two sites on Lake Creek in the Upper Missouri-Dearborn TMDL Planning Area for the purpose of assessing whether this stream is water-quality limited and in need of TMDLs. The samples were collected following MDEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Diatom metrics indicate impairment at both sites from sedimentation and organic loading. Although impairment from sedimentation was moderate at the upstream site and minor at the downstream site, the downstream site supported a larger percentage of highly motile diatoms, suggesting that this site had more unstable substrates. Diatoms also indicate higher levels of dissolved solids and organic nitrogen at the downstream site. Diatoms at both sites indicate alkaline and eutrophic waters with 25 - 70% dissolved oxygen saturation and 4-13 mg/L BOD₅.

Conspicuous macroalgae were absent at the upstream site, whereas at the downstream site the filamentous green algae *Rhizoclonium* and *Schizomeris* were abundant and common, respectively. *Rhizoclonium* is a common nuisance alga in streams of the western United States. *Schizomeris* is most common in eutrophic waters, including waters below discharges from sewage treatment plants.

Introduction

This report evaluates the biological integrity¹, support of aquatic life uses, and probable causes of stress or impairment to aquatic communities in Lake Creek near Great Falls in north central Montana. The purpose of this report is to provide information that will help the State of Montana determine whether Lake Creek is water-quality limited and in need of TMDLs.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

Evaluation of aquatic life use support in this report is based on the species composition and structure of periphyton (benthic algae, phytobenthos) communities at two stream sites that were sampled in September 2003. Periphyton is a diverse assortment of simple photosynthetic organisms called algae that live attached to or in close proximity of the stream bottom. Some algae form long filaments or large colonies and are conspicuous to the unaided eye. But most, including the ubiquitous diatoms, can be seen and identified only with the aid of a microscope. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity in Montana streams (Bahls et al. 1992). Plafkin et al. (1989) and Barbour et al. (1999) list several advantages of using periphyton in biological assessments.

¹ *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

Project Area and Sampling Sites

The project area is located in north central Montana in Teton County north of Great Falls. Lake Creek is a tributary of Benton Lake in Benton Lake National Wildlife Refuge. Lake Creek heads on the Teton Ridge near Power, Montana and then flows southeasterly into Benton Lake. Although included in the Upper Missouri-Dearborn HUC (10030102), Benton Lake has no surface outlet to the Missouri River. The Lake Creek-Benton Lake watershed is entirely within the Northwestern Glaciated Plains Ecoregion (Woods et al. 1999).

Periphyton samples were collected at two sites on Lake Creek (Table 1). Both sampling sites are at an elevation of about 3,600 feet above mean sea level. Vegetation in the study area is mixed grassland (USDA 1976). Land use is primarily dryland farming, livestock grazing, and waterfowl production in Benton Lake. Lake Creek is classified B-3 in the Montana Surface Water Quality Standards.

Methods

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the importance of those substrates at each study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's (IKI) solution.

The samples were examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Smith (1950), Prescott (1962, 1978), John et al. (2002), and Wehr and Sheath (2003). These books also served as references on the ecology of the soft algae, along with Palmer (1969, 1977).

After the identification of soft algae, the raw periphyton samples were cleaned of organic matter using sulfuric acid, potassium dichromate, and 3% hydrogen peroxide. Then, permanent diatom slides were prepared using Naphrax®, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). At least 300 diatom cells (600 valves) were counted at random and identified to species. The following were the main taxonomic references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Lange-Bertalot 2001; Krammer 2002. Where applicable, conventions for diatom nomenclature followed those adopted by the Integrated Taxonomic Information System (<http://www.itis.usda.gov>). For taxa not included in ITIS, naming conventions followed those adopted by the Academy of Natural Sciences for USGS NAWQA samples (Morales and Potapova 2000). Van Dam et al. (1994) was the main ecological reference for the diatoms.

The diatom proportional counts were used to generate an array of diatom association metrics. A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999). Diatoms are particularly useful in generating metrics because there is a wealth of information available in the literature regarding the pollution tolerances and water quality preferences of common diatom species (e.g., Lowe 1974, Beaver 1981, Lange-Bertalot 1996, Van Dam et al. 1994).

Values for selected metrics were compared to biocriteria (numeric thresholds) developed for streams in the Great Plains ecoregions of Montana (Table 2). These criteria are based on the distribution of metric values measured in least-impaired reference streams (Bahls et al. 1992) and metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993). The biocriteria in Table 2 are valid only for samples collected during the summer field season (June 21-September 21).

The criteria in Table 2 distinguish among four levels of stress or impairment and three levels of aquatic life use support: (1) no impairment or only minor impairment (full support); (2) moderate impairment (partial support); and (3) severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor biological integrity, respectively.

Quality Assurance

Several steps were taken to assure that the study results are accurate and reproducible. Upon receipt of the samples, station and sample attribute data were recorded in the Montana Diatom Database and the samples were assigned a unique number, e.g., 3004-01. The first part of this number (3004) designates the sampling site (Lake Creek above Hevron Road) and the second part (01) designates the number of periphyton samples that have been collected at this site for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with information on the sample label. A portion of the raw sample was used to make duplicate diatom slides. The slide used for the diatom proportional count will be deposited in the Montana Diatom Collection at the University of Montana Herbarium in Missoula. The duplicate slide will be retained in the offices of *Hanna* in Helena. Diatom proportional counts have been entered into the Montana Diatom Database.

Results and Discussion

Results are presented in Tables 3, 4, and 5, which are located near the end of this report following the references section. Appendix A consists of two diatom reports, one for each sample. Each diatom report contains an alphabetical list of diatom species and their percent abundances, and values for 65 different diatom metrics and ecological attributes.

Sample Notes

Lake Creek above county road. The *Rhizoclonium* in this sample consisted of short (1-3 cell) filaments only. The sample contained moderately heavy amounts of medium-coarse (5-15 micron diameter) inorganic sediment.

Lake Creek above Hevron Road. The sample from this site contained an abundance of fine particulate organic matter but little inorganic sediment.

Non-Diatom Algae

The sample from the upstream site above the county road was dominated by diatoms, followed in abundance by the blue-green alga *Oscillatoria* and occasional cells of the filamentous green alga *Rhizoclonium* (Table 3). *Rhizoclonium* was dominant at the downstream site, followed by diatoms, the filamentous green alga *Schizomeris*, and the desmid *Closterium*. *Rhizoclonium* is a common mat-forming and nuisance alga in streams of the western United States. *Schizomeris* is most common in eutrophic waters, including polluted environments such as sewage sludge or shallow lakes close to discharges from sewage treatment plants (Wehr and Sheath 2003). It grows in quiet waters as dark green, coarse clumps and is widespread but not common.

Diatoms

Five of the major diatom species in Lake Creek are sensitive to organic pollution and were present at both sites (Table 4). Six of the major species are somewhat tolerant of organic pollution and most of these were also present at both sites. *Navicula veneta*, *Nitzschia palea*, and *Nitzschia pusilla* are very tolerant of organic pollution. Each site supported the same total percent abundance of these very tolerant species (16.1%).

Lake Creek above county road. Diatom metrics indicate **moderate impairment from sedimentation** and minor impairment from organic loading at this site (Table 4). Otherwise, diatom metrics indicate no impairment and full support of aquatic life uses.

Lake Creek above Hevron Road. This site supported fewer species than the upstream site and had a lower diversity index value. The pollution index value was nearly identical to the upstream site and indicates **minor impairment** from organic loading. The sedimentation index was somewhat lower than upstream and indicated minor impairment. A large percent abundance of *Nitzschia inconspicua* indicated minor stress. Since *Nitzschia inconspicua* is a highly motile diatom and a facultative nitrogen heterotroph (Van Dam et al. 1994), this stress is probably due to sedimentation and elevated levels of organic nitrogen. This site shared only about one-third of

its diatom assemblage with the upstream site, indicating that a moderate amount of floristic and environmental change occurred between them.

Modal Categories

Several ecological attributes were selected from the diatom reports in the appendix and modal categories of these attributes were extracted to characterize water quality tendencies at the two sites (Table 5).

Modal categories at both sites indicate alkaline and eutrophic waters with 25 - 70% dissolved oxygen saturation and 4-13 mg/L BOD₅. However, other modal categories suggest that the downstream (Hevron Road) site had more unstable substrates (more highly motile diatoms), higher concentrations of dissolved solids (more brackish-fresh diatoms), and higher levels of organic nitrogen (more nitrogen heterotrophs) than the upstream site (Table 5).

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Table 1. Location of MDEQ periphyton sampling stations on Lake Creek near Power, Montana in 2003.

Station	Montana DEQ Station Code	<i>Hannaea</i> Sample Number	Latitude	Longitude	Sample Date
Lake Creek above county road	M12LAKEC01	3003-01	47 42 52	111 33 37	9/4/03
Lake Creek above Hevron Road	M12LAKEC02	3004-01	47 42 41	111 25 49	9/4/03

Table 2. Diatom association metrics used by the State of Montana to evaluate biological integrity in **prairie** streams: references, range of values, expected response to increasing impairment or natural stress, and criteria for rating levels of biological integrity. The lowest rating for any one metric is the rating for that site.

Biological Integrity/ Impairment or Stress/ Use Support	No. of Species Counted ¹	Diversity Index ² (Shannon)	Pollution Index ³	Siltation Index ⁴	Disturbance Index ⁵	% Dominant Species ⁶	Similarity Index ⁷
Excellent/None Full Support	>39	>3.99	>2.25	<50.0	<25.0	<25.0	>59.9
Good/Minor Full Support	30-39	3.00-3.99	1.76-2.25	50.0-69.9	25.0-49.9	25.0-49.9	40.0-59.9
Fair/Moderate Partial Support	20-29	2.00-2.99	1.25-1.75	70.0-89.9	50.0-74.9	50.0-74.9	20.0-39.9
Poor/Severe Nonsupport	<20	<2.00	<1.25	>89.9	>74.9	>74.9	<20.0
References	Bahls 1979 Bahls 1993	Bahls 1979	Bahls 1993	Bahls 1993	Barbour et al. 1999	Barbour et al. 1999	Whittaker 1952
Range of Values	0-100+	0.00-5.00+	1.00-3.00	0.0-90.0+	0.0-100.0	~5.0-100.0	0.0-100.0
Expected Response	Decrease	Decrease	Decrease	Increase	Increase	Increase	Decrease

¹Based on a proportional count of 400 cells (800 valves)

²Base 2 [bits] (Weber 1973)

³Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species

⁴Sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*

⁵Percent abundance of *Achnanthes minutissimum* (synonym: *Achnanthes minutissima*)

⁶Percent abundance of the species with the largest number of cells in the proportional count

⁷Percent Community Similarity (Whittaker 1952)

Table 3. Relative abundance of cells and ordinal rank by biovolume of diatoms (Division Bacillariophyta) and genera of non-diatom algae in periphyton samples collected from Lake Creek in 2003.

Taxa	Lake Creek above county road M12LAKEC01	Lake Creek above Hevron Road M12LAKEC02
Cyanophyta (cyanobacteria)		
<i>Oscillatoria</i>	abundant/2nd	
Chlorophyta (green algae)		
<i>Closterium</i>		occasional/4th
<i>Rhizoclonium</i>	occasional/3rd	dominant/1st
<i>Schizomeris</i>		common/3rd
Bacillariophyta (diatoms)	dominant/1st	abundant/2nd
# Non-Diatom Genera	2	3

Table 4. Percent abundance of major diatom species¹ and values of selected diatom association metrics for periphyton samples collected from Lake Creek in 2003. Underlined values indicate minor stress; **bold values** indicate moderate stress; **underlined and bold** values indicate severe stress; all other values indicate no stress and full support of aquatic life uses when compared to criteria for plains streams in Table 2.

Species/Metric	PTC ²	Lake Creek above county road M12LAKEC01	Lake Creek above Hevron Road M12LAKEC02
<i>Cocconeis placentula</i>	3	6.79	0.77
<i>Cymbella excisa</i>	3	0.95	4.95
<i>Gomphonema minutum</i>	3	1.58	15.63
<i>Navicula capitatoradiata</i>	2	12.01	3.87
<i>Navicula erifuga</i>	2	2.05	4.49
<i>Navicula gregaria</i>	2	6.16	2.79
<i>Navicula lanceolata</i>	2	7.11	
<i>Navicula reichardtiana</i>	2	3.16	
<i>Navicula veneta</i>	1	7.11	5.42
<i>Nitzschia dissipata</i>	3	4.58	0.31
<i>Nitzschia inconspicua</i>	2	1.42	30.34
<i>Nitzschia palea</i>	1	5.37	0.93
<i>Nitzschia pusilla</i>	1		5.57
<i>Rhoicosphenia abbreviata</i>	3	4.11	2.17
Number of Species Counted		59	48
Shannon Species Diversity		4.99	<u>3.97</u>
Pollution Index		<u>2.15</u>	<u>2.16</u>
Siltation Index		72.99	63.16
Disturbance Index		1.58	2.32
Percent Dominant Species		12.01	<u>30.34</u>
Percent Abnormal Cells		0.00	0.00
Similarity Index ³			33.97

¹A major diatom species accounts for 3.0% or more of the cells at one or more stations in a sample set.

²(Organic) Pollution Tolerance Class (Lange-Bertalot 1979): 1 = most tolerant; 2 = tolerant; 3 = sensitive.

³Percent Community Similarity (Whittaker 1952) when compared to the diatom assemblage at the adjacent upstream station

Table 5. Modal categories for selected ecological attributes of diatom species in Lake Creek. Categories that represent significant declines in water quality from the upstream site to the downstream site are given in **bold type**.

Ecological Attribute	Lake Creek above county road M12LAKEC01	Lake Creek above Hevron Road M12LAKEC02
Motility ¹	Moderately Motile	Highly Motile
pH ²	Alkaliphilous	Alkaliphilous
Salinity ²	Fresh	Brackish-Fresh
Nitrogen Uptake ²	Autotrophs (tolerate high organics)	Facultative Nitrogen Heterotroph
Oxygen Demand ²	Moderate	Moderate
Saprobity ²	alpha-Mesosaprobous	alpha-Mesosaprobous
Trophic State ²	Eutraphentic	Eutraphentic

¹Dr. R. Jan Stevenson, Michigan State University, digital communication.

²Van Dam et al. 1994

